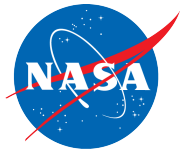


Jet Propulsion Laboratory

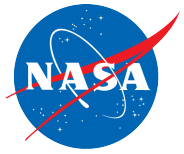
Onboard Radar Processing Concepts for the DESDynI Mission

Yunling Lou, Steve Chien, Duane Clark, and Joshua Doubleday

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

NASA Earth Science Technology Forum
22-24 June, 2010
Arlington, Virginia

Earth Science Technology Office



Agenda

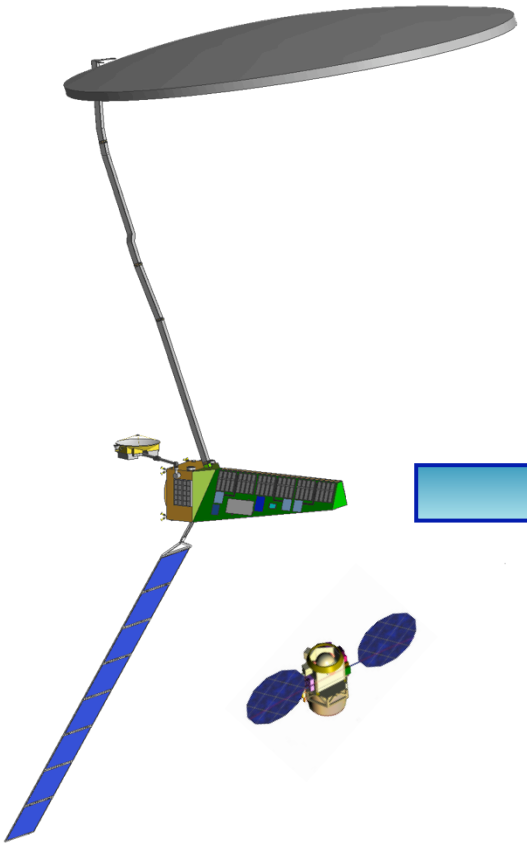
Jet Propulsion Laboratory

- DESDynI mission measurements overview
- Benefits of onboard processing technology
- Approach to onboard product development
- Examples of onboard products
- Future work

ESTO
Earth Science Technology Office

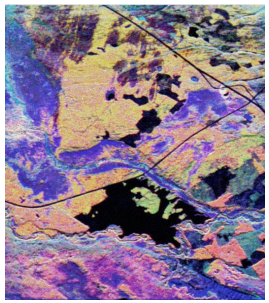
DESDynI Mission Measurements Overview

Jet Propulsion Laboratory

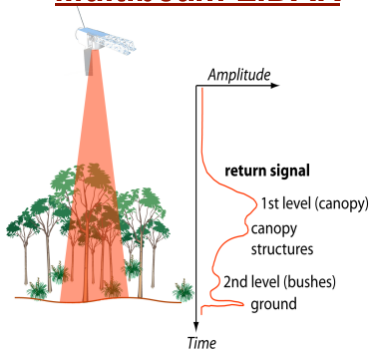


DESDynI will exploit an L-band polarimetric radar operated interferometrically (InSAR) and multibeam lidar

Polarimetric SAR



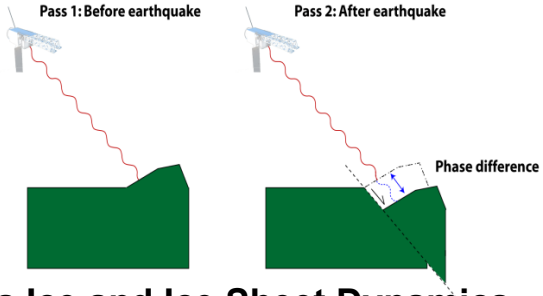
Multibeam LIDAR



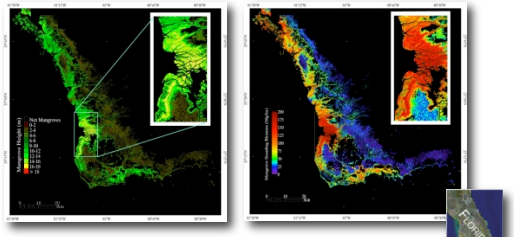
Biomass
Vegetation Structure
Vegetation Disturbance
Sea Ice Thickness

Repeat Pass InSAR

Pass 1 Pass 2

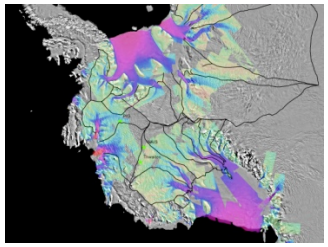


Sea Ice and Ice Sheet Dynamics
Changes in Earth's Surface

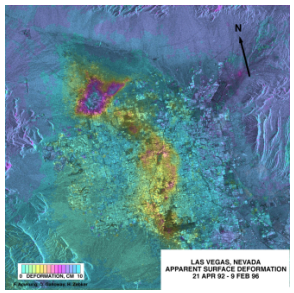


Simard et al (2006,2008)

Effects of changing climate on habitats and CO_2



Response of ice sheets to climate change & sea level rise



Water Resource Management
Geo-Hazards

DESDynI - Deformation, Ecosystem Structure, and Dynamics of Ice

Potential Advantages of Onboard Processing for DESDynI Mission

- DESDynI Radar is an L-band polarimetric Synthetic Aperture Radar (SAR) instrument
  - Single/Dual-Pol Repeat-pass Interferometric data for solid earth and ice deformation
  - Dual and Quad-Pol data for ecosystem structure
  - Experimental Quad-Pol Repeat-pass Interferometric data for ecosystem structure
- Expected data rate is 1 - 2 Gbps instantaneous or ~350 Mbps orbital average to meet the high resolution and extensive coverage of the proposed measurements
  - Current mission design uses a 1 Gbps TDRSS link and 8 Tbit onboard data storage (RPI requirement)
- Appropriate onboard processing technology could reduce onboard data storage and downlink data volume for some non-interferometric data products
  - Azimuth pre-filtering of raw data using OBP techniques can reduce data volume and rates to the ground by 15-20%

- OBP will enable more frequent ecosystem and cryospheric science observations than currently feasible
- Most disaster response applications would not be possible without onboard processing

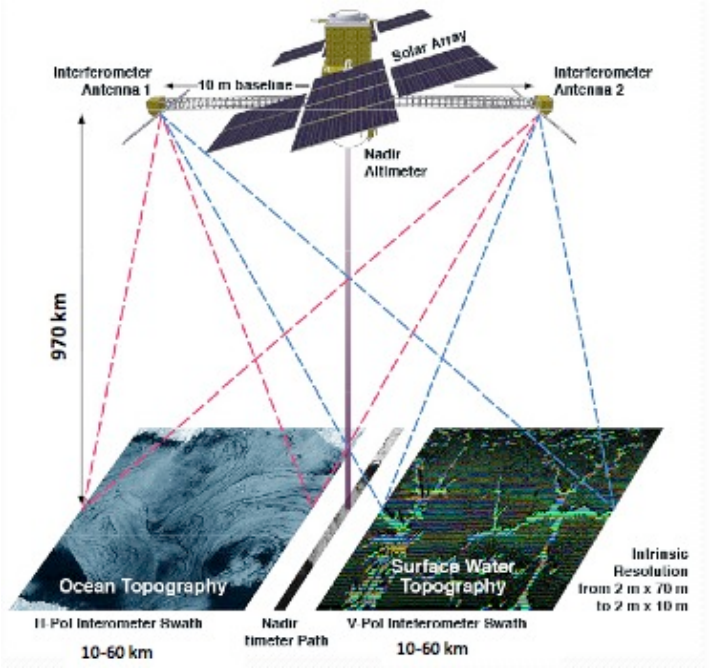
Benefits of Onboard Processing Technology for DESDynI Mission

	Solid Earth	Ecosystem Structure	Cryospheric Science
Desired Repeat Interval	Weekly; Rapid imaging of a disaster	Monthly	Weekly for ice sheets; 2 days for sea ice (in wide swath mode)
Target Sites	All major tectonic plate boundaries, intra-plate locations with historical earthquake activity, the world's 600 potentially active volcanoes, and other areas where detailed deformation observations are useful.	Global wall-to-wall coverage of vegetated surface.	Entire ice sheets in Greenland and Antarctica, including south pole and over smaller glaciated areas in other continents and over areas underlain by permafrost. Sea ice in Arctic and Antarctic oceans.
Desire Products	Surface deformation, correlation, and velocity maps	Forest biomass, soil moisture, vegetation classification, land use classification	Correlation maps, ice stream velocity, sea ice monitoring, freeze/thaw maps
Polarization	Single/Dual/Occasional Quad	Quad	Single or Dual
Spatial Resolution	10 to 20 m	25 m (vegetation height); 100 m to 1 km (forest biomass)	2 to 5 m (ice sheet displacement); 100 m (sea ice formation)
Swath Width	350 km (60 km in Quad)	200 km	350 km
Raw Data Rate	580 to 1160 Mbps	2000 Mbps	580 to 1160 Mbps
Potential Onboard Products	Compressed interferogram	Forest biomass, soil moisture, vegetation classification, land use classification	Sea ice classification, freeze/thaw maps
Potential Downlink Data Volume Reduction Factor	10, but only for limited scenes that can be stored on board	1000	1000 for sea ice (non-interferometric)
Potential Disaster Response Products	Earthquake, Flooding, lava flow	Forest fuel load, hurricane damage in forest, flooding	Ice melting, ship channel freeze/thawing

Other Potential Advantages of Onboard Processing for Earth Science Radar Missions

Jet Propulsion Laboratory

Radar missions that can take best advantage of OBP are those where raw data are not needed on the ground. OBP can achieve data rate reduction of 1000 or more

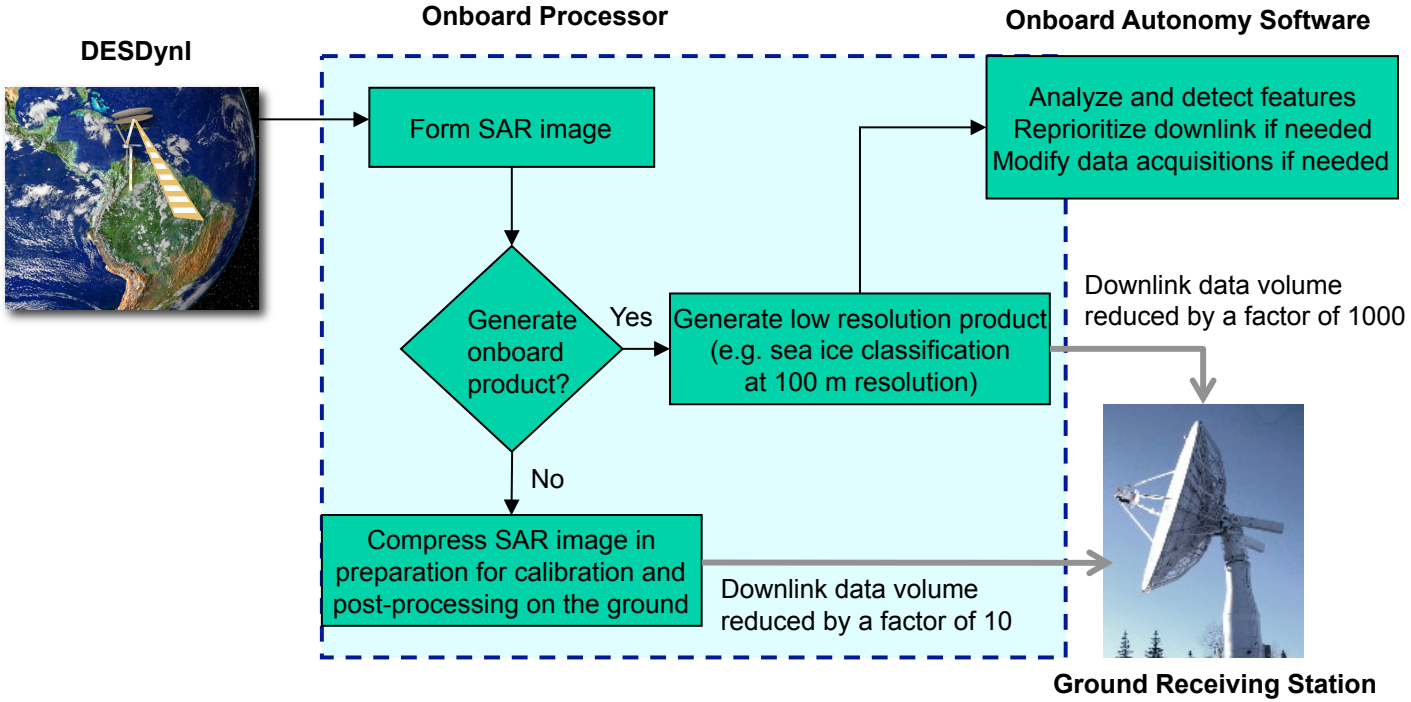


- Earth orbiting single-pass interferometry missions: SWOT, Tandem-L?
- Planetary single-pass interferometry mission concepts: Ka-band Europa Topo-mapper, X-band Venus Topo-mapper
- Earth orbiting polarimetry-only missions: BIOMASS?
- Airborne UAV systems designed for monitoring and rapid response using polarimetric or amplitude change techniques

Examples of rapid response applications:

- Solid earth: earthquake, flooding, lava flow
- Ecosystem: forest fuel load, hurricane damage in forest, flooding
- Cryosphere: ice melting, ship channel freezing/thawing

Onboard Processing Scenario for DESDynI Mission's Radar Instrument

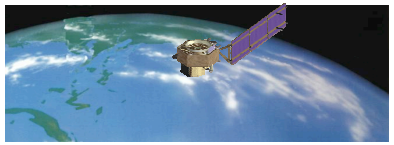


- Downlink data volume reduction factor is directly proportional to the level of onboard processing involved:
  - With SAR image formation followed by image compression technique, a factor of 10 in data volume reduction is expected
  - With SAR image formation followed by science data processing for specific feature detection applications, downlink data volume can be reduced by a factor of 1000
- Ability to generate targeted products onboard will enable rapid response to natural hazards via Direct Broadcast

Example Mission Scenario with Autonomous Sciencecraft Experiment

Jet Propulsion Laboratory

Image taken by Spacecraft

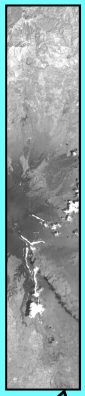


Onboard Science Analysis

Event Detection

No event Detected: Delete Image

Event Detected



ASE uses state of the art Machine Learning to detect events in the presence of noise

Track a wide range of science events – floods, volcanoes, cryosphere, clouds,…

Key Insight: No need to replicate ground science analysis – just detect activity

ESTO Earth Science Technology Office

Approach to Onboard Product Development

- Determine the types of data processing suitable for implementation onboard the spacecraft to achieve the highest data compression gain without sacrificing science objectives
  - SAR image formation
  - Polarimetric calibration
  - Multilooking
  - Cross-correlation
  - Simple classification techniques
- Adapt complex science algorithms for onboard processing to generate 100 m resolution products such as forest biomass, flood scene map, sea ice classification, and correlation map for change detection
- Identify product applications currently not included in the mission objectives

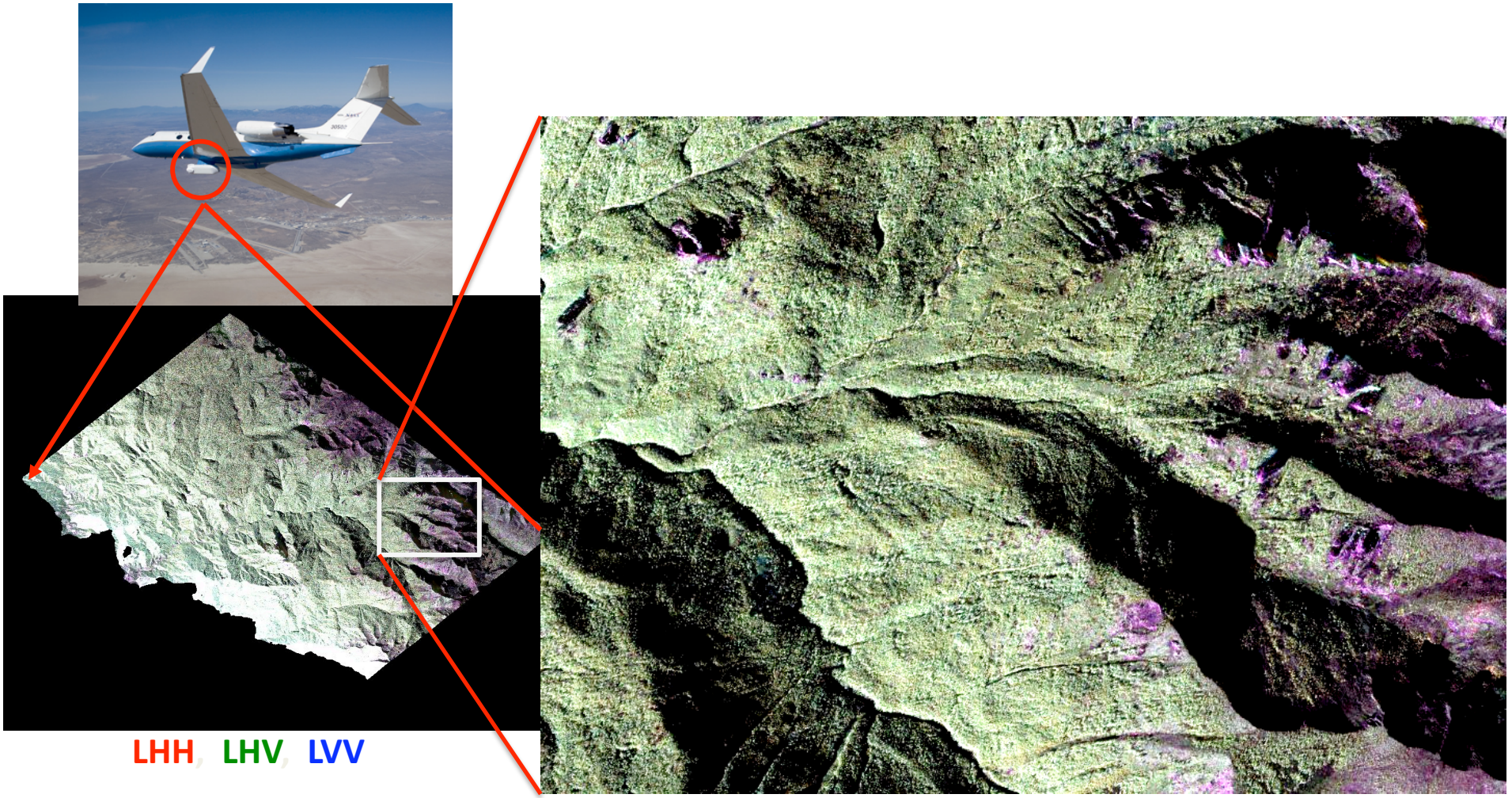
Forest Fire Extent

Jet Propulsion Laboratory

Tracking forest fire extent with UAVSAR L-band polarimetric data products

ESTO
Earth Science Technology Office

Forest Fuel Load



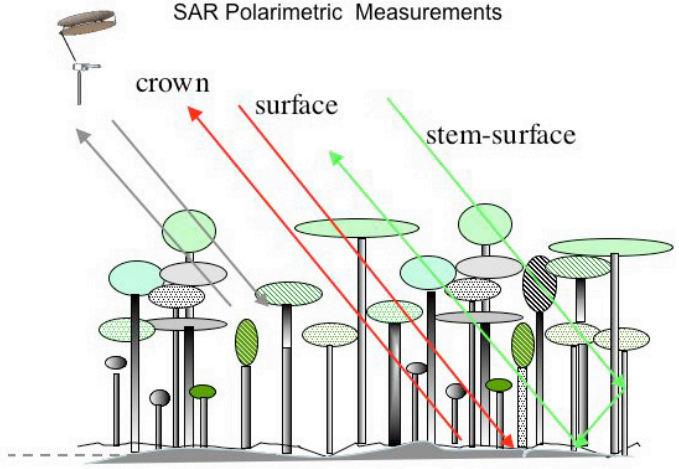
UAVSAR Onboard Algorithm for Mapping Forest Fuel Load
A Dual-Pol Approach

Post-processing Steps

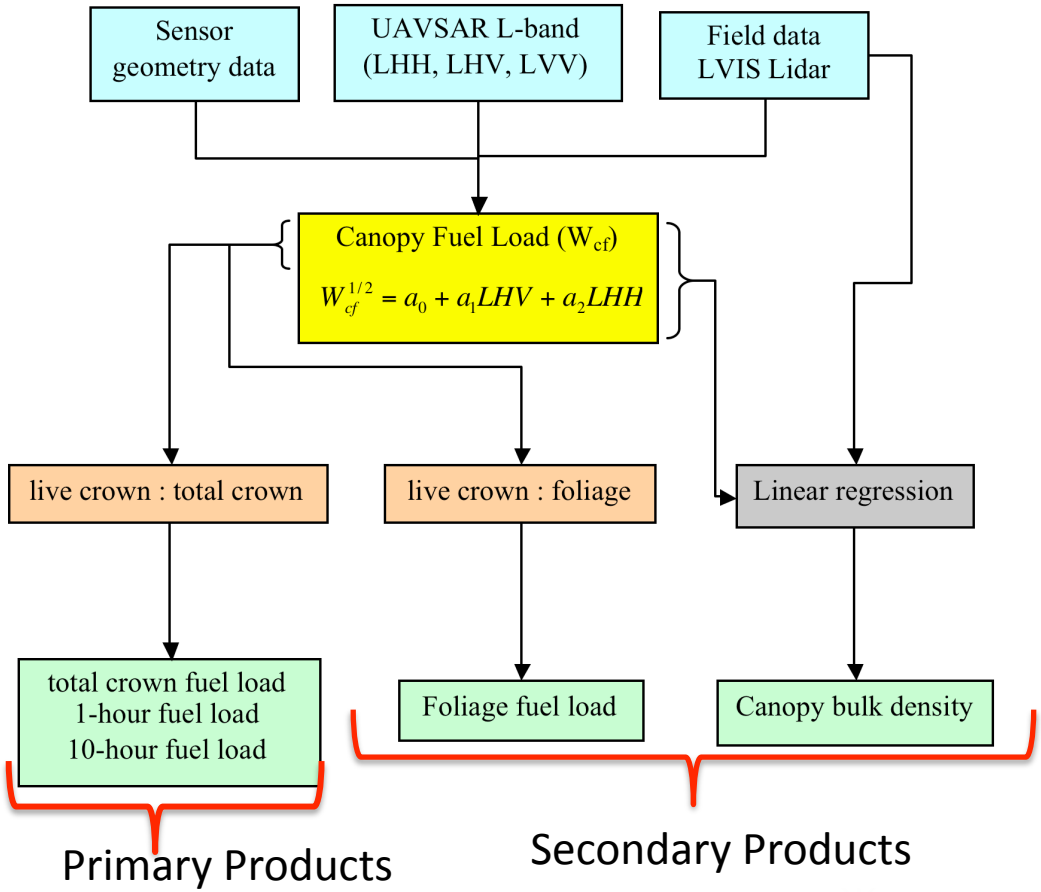
1.Image Calibration

2.Image Ortho-rectification using Available Terrain Models

3.Backscatter Power in ground range Projection at 10-100 m spatial Resolution



Fuel Load Model

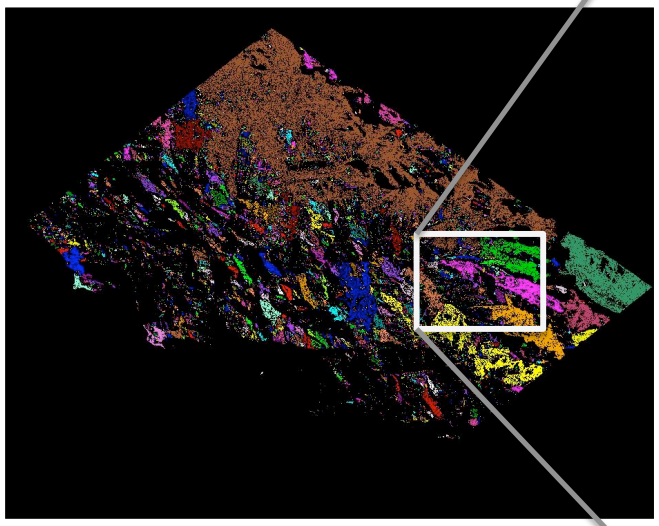


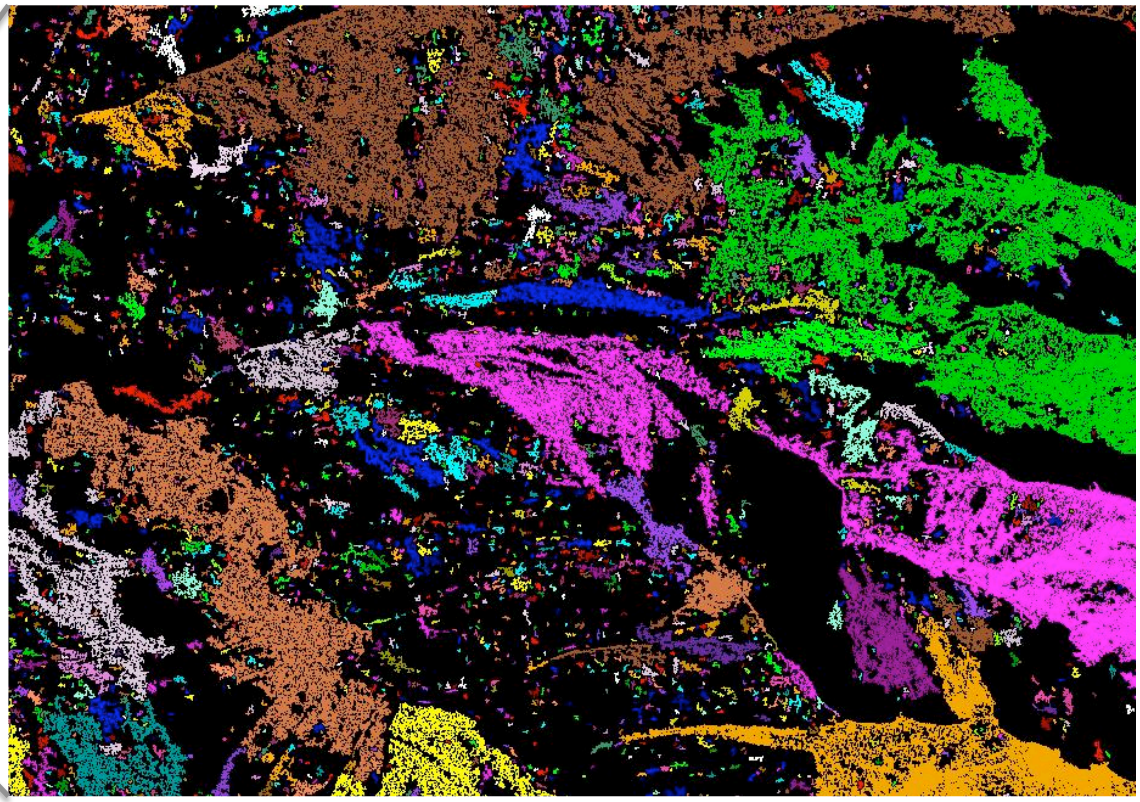
UAVSAR Fuel Products

Jet Propulsion Laboratory

Distribution of 1-hr Branch Fuel Load

Low Fuel Load Forests





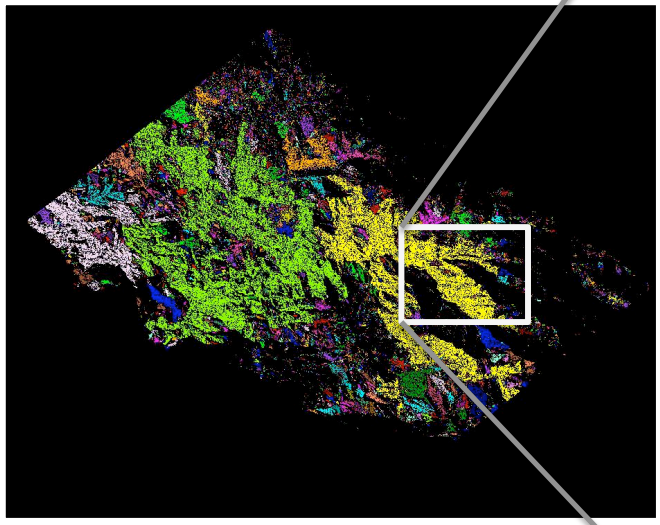
We collected field data in Kings Canyon to verify the fuel load determination

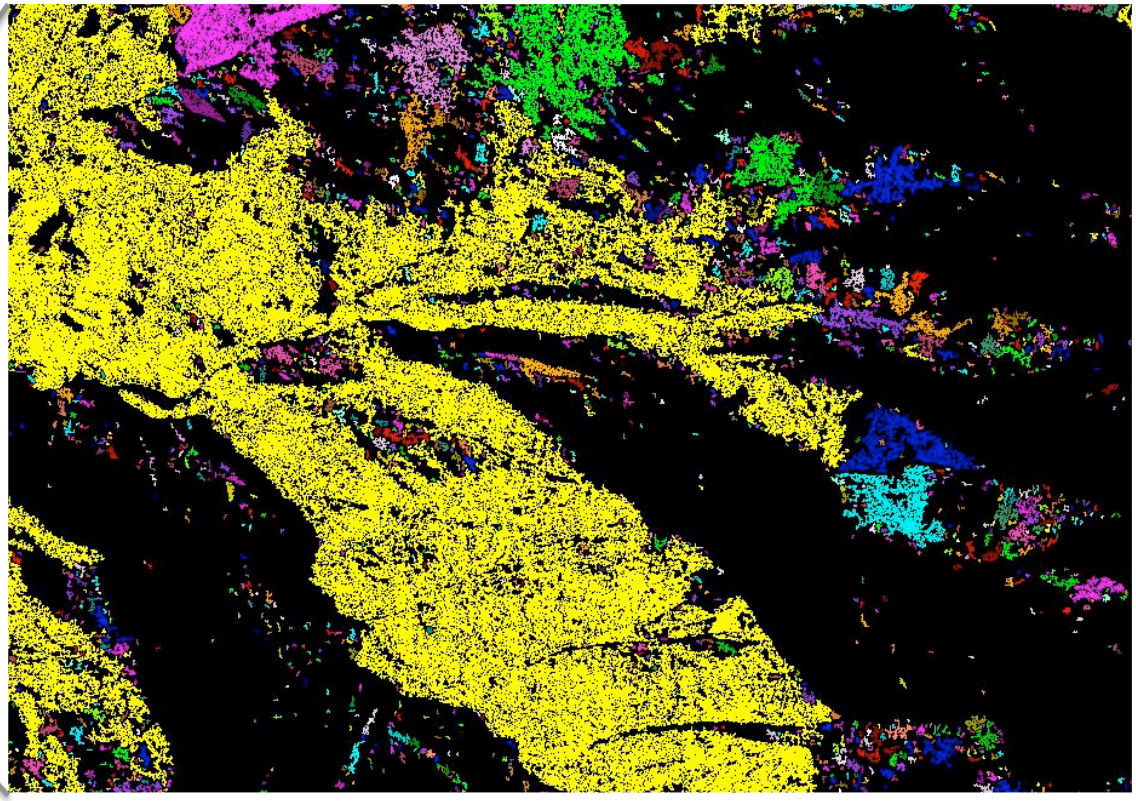
UAVSAR Fuel Products

Jet Propulsion Laboratory

Distribution of 10-hr Branch Fuel Load

Medium Fuel Load Forests



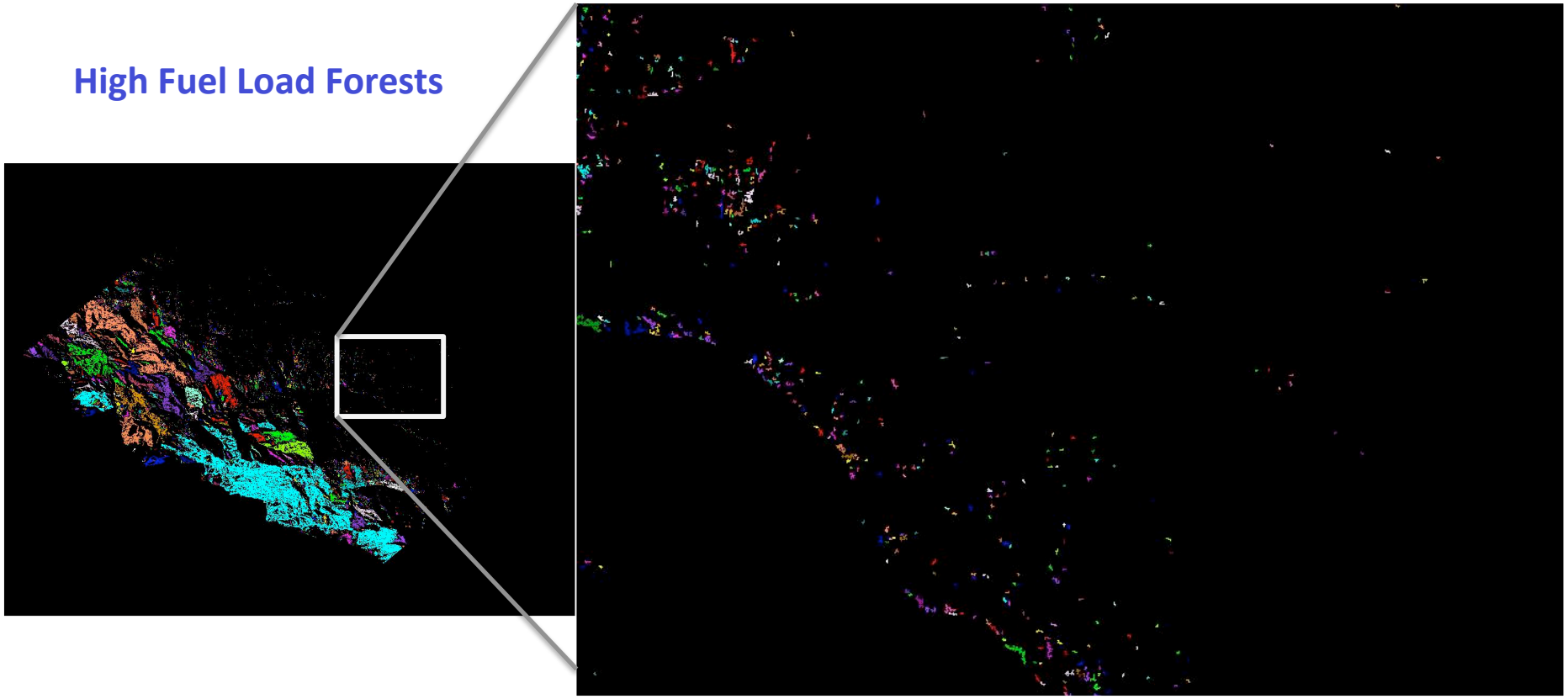


UAVSAR Fuel Products

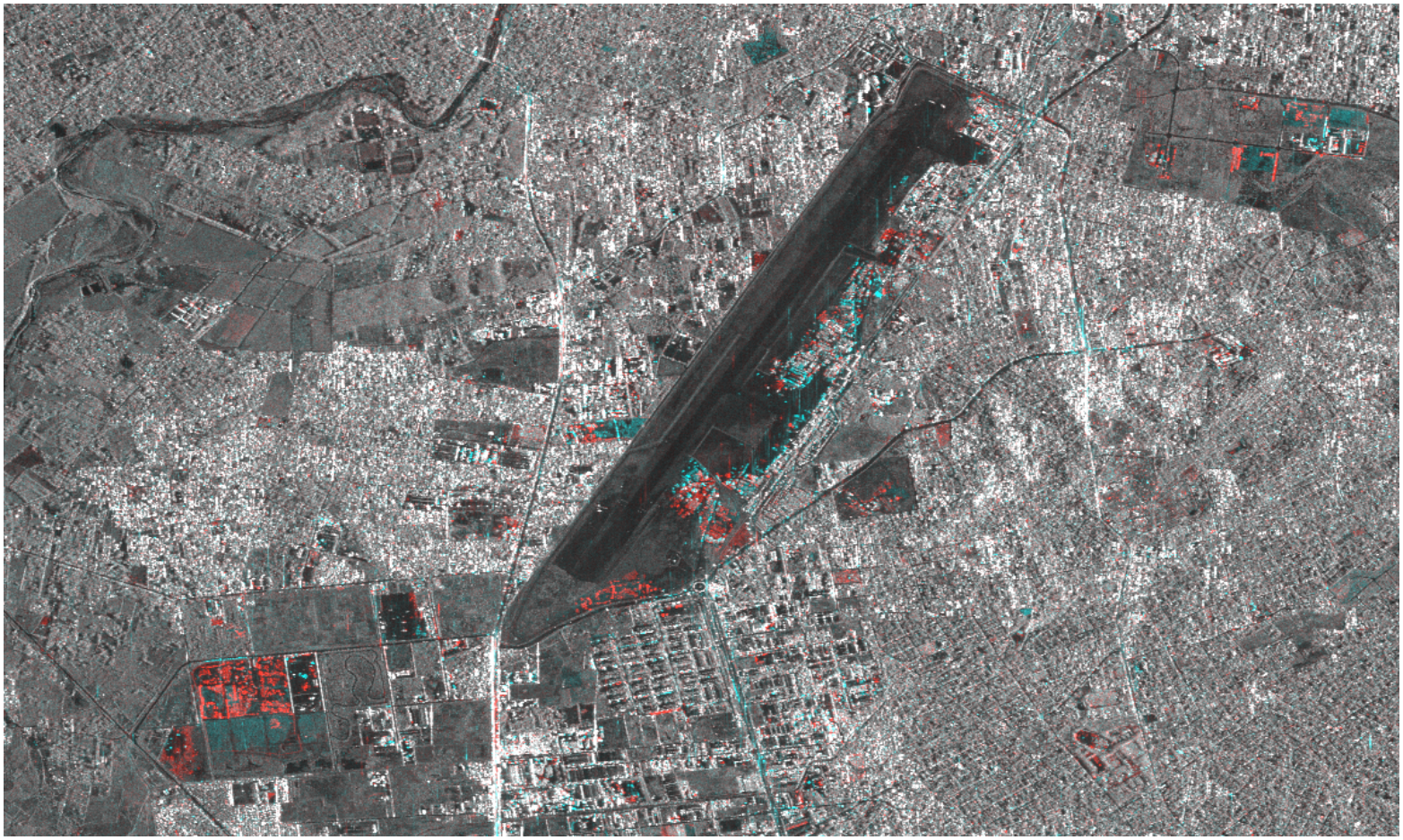
Jet Propulsion Laboratory

Distribution of 100-hr Branch Fuel Load

High Fuel Load Forests



Earthquake Damage Assessment with Amplitude Change Detection



Jan 27, 2010

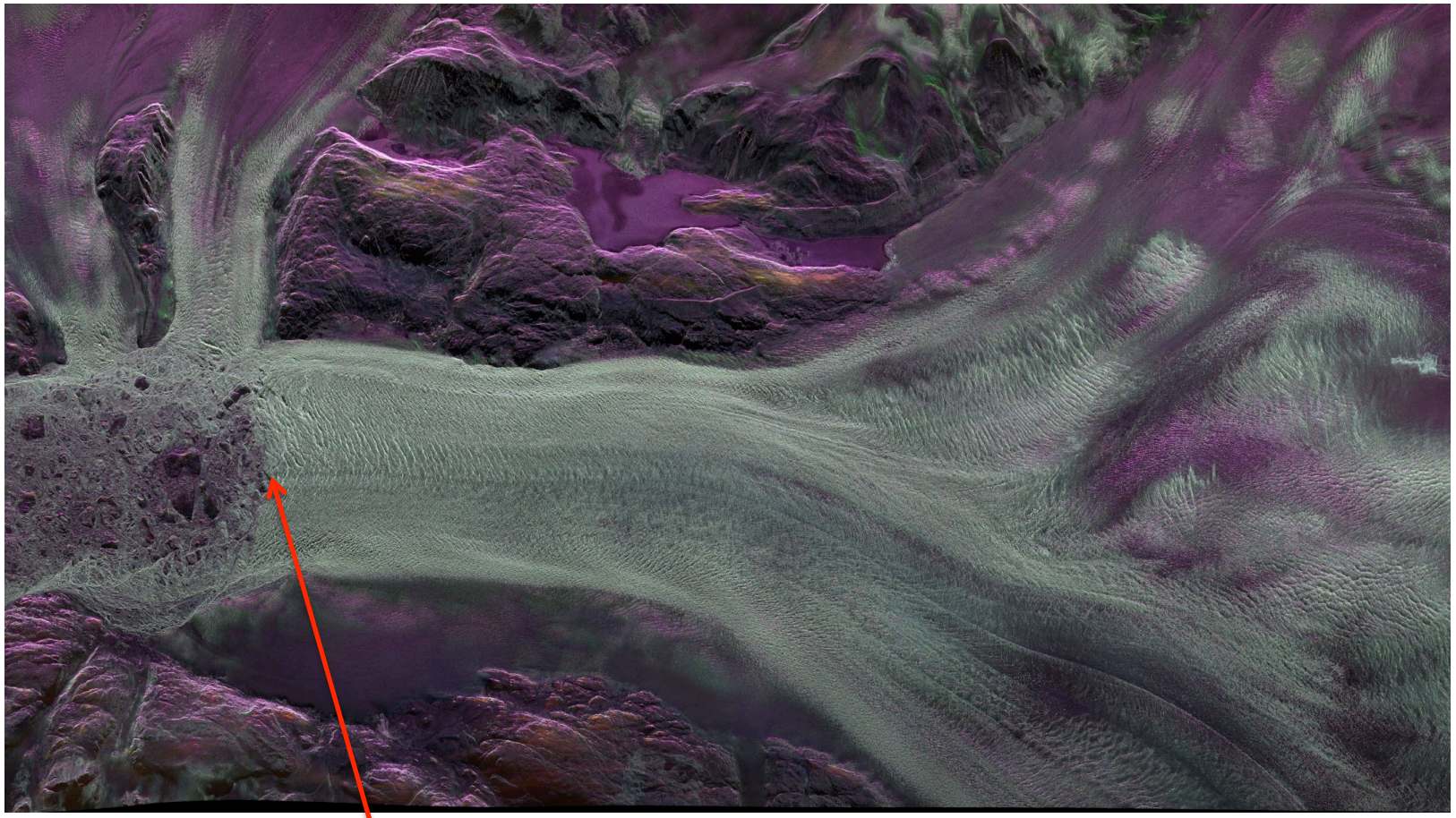
Feb 13, 2010

UAVSAR's 16-day Repeat Pass Data over Port Au Prince Airport, Haiti

By comparing two post-earthquake amplitude images, we are able to identify old features (green) that have been removed (perhaps damaged buildings) and new features (red) that have been built (perhaps tent cities) over a two-week period.

Glacier Melting

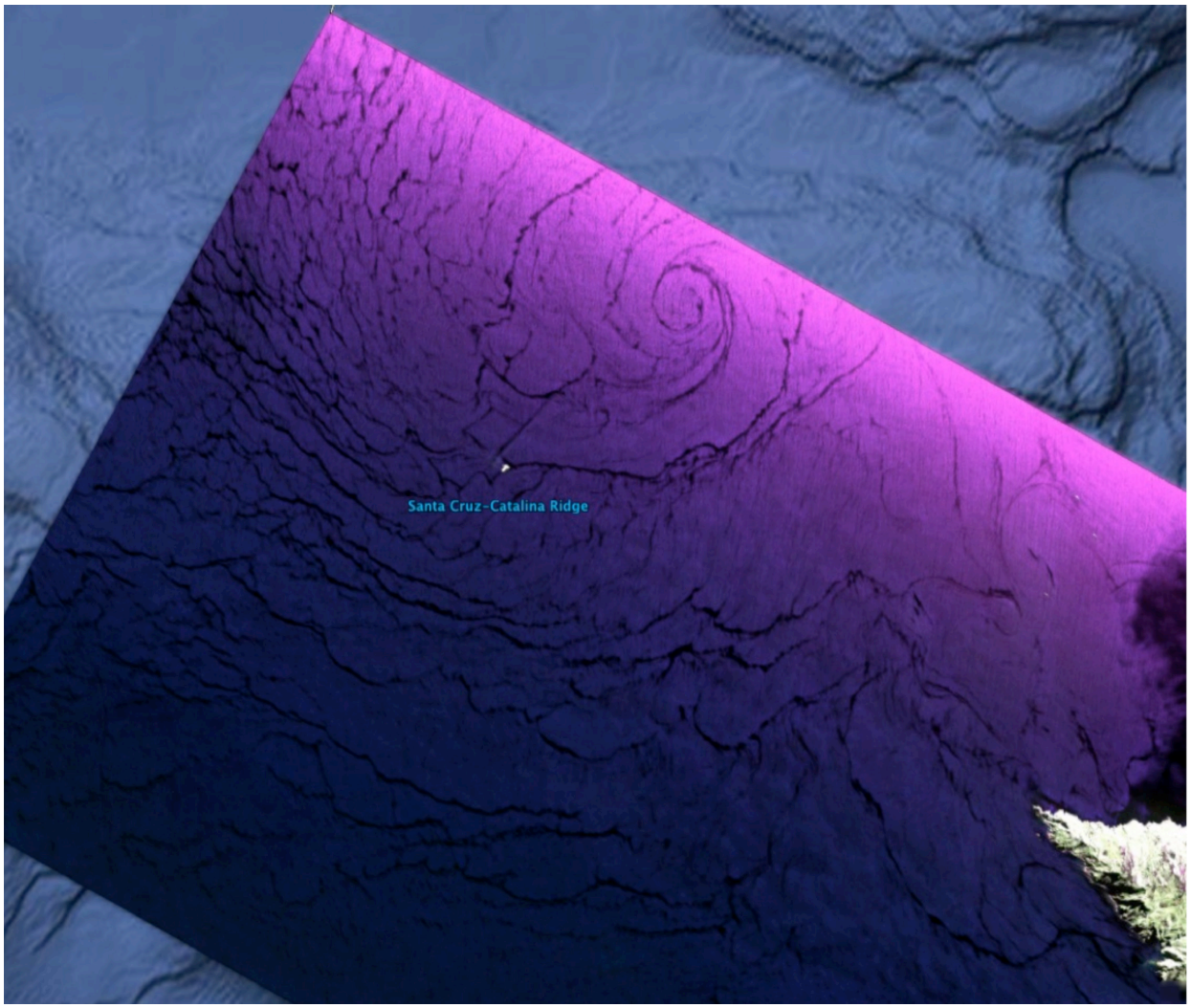
L-band polarmetric image of the Kangerlugssuaq ice fjord in Eastern Greenland. The grounding line of the glacier is easily identifiable in the image



Coastal Eddies

Jet Propulsion Laboratory

Tracking coastal eddies (a short transient event) with UAVSAR L-band data



LHH, LHV, LVV

Earth Science Technology Office

Future Work

- Prototype additional rapid response application products
  - Flood extent
  - Lava flow
  - Hurricane damage
  - Ice melting (ship channel and ground thawing)
- Utilize machine learning to classify some of the products for event detection and onboard replanning
- Prototype products for long term monitoring applications
  - Vegetation type classification
  - Soil moisture monitoring